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Considerations for Survivability Mapping of Obscurant Effects

by James F. Nealon

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Aberdeen Proving Ground, MD 21010-5423

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Considerations for Survivability Mapping of Obscurant Effects

James F. Nealon
Survivability/Lethality Analysis Directorate, ARL

Abstract

Obscurant effects were not described in sufficient detail in the U.S. Army Research Laboratory's Survivability/Lethality Analysis Directorate (SLAD) vulnerability/lethality (VL) taxonomy. There were shortcomings in coupling the obscurant effects to target engagement, missile flyout, and probability of hit (Ph) that surfaced during modeling for the Improved Bradley Acquisition System (IBAS). This report describes the methodology used to fix these shortcomings. Obscurant effects are described and are related to effects on target engagement and hit. The report concludes with a set of logical steps and procedures to implement this methodology in a larger VL framework.

Table of Contents

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1. Purpose

This report comes from a request by Brian Ruth, U.S. Army Research Laboratory Survivability/Lethality Analysis Directorate (SLAD) Ballistics and NBC Division (BND), to examine how obscurant characteristics can affect probability of hit (Ph) for a tube-launched, optically tracked, wire-guided (TOW) II family missile.

2. Background

An integrated analysis program is being built for the Bradley A3 vehicle. SLAD is attempting to integrate numerous vulnerability/lethality (VL) disciplines to address effects on system survivability, via the SLAD taxonomy. Sufficient information exists for the Improved Bradley Acquisition System (IBAS) to allow calculation of probability of identification. There is insufficient information to directly calculate the ability to engage a target and successfully hit/kill it. It was necessary to review existing data for obscurant effects on missile guidance and to provide input on how to address this portion of the problem.

3. Methodology Approach

Based on existing tasks and information from field manuals, the Bradley gunner will fire the TOW II family missile when a target is identified as hostile. This requires detection, classification, and recognition first. Obscurants can affect the preceding steps by making a target have less contrast with it surroundings, suppressing its signature, and adding additional clutter to the scene. The effect, when modeled in ACQUIRE, is to shorten the distance for detection, recognitions, etc., and also to increase the time required to detect, recognize, and identify a target. ACQUIRE is a target acquisition model developed by the Night Vision/Electronic Systems Directorate of U.S. Army Communications and Electronics Command. Thus, the obscurant limit (for target engagement) is limited by obscurant characteristics optical density

1

([OD] and target range pairs, usually) for the 2nd-generation, forward-looking infrared (FLIR) sight.

If the gunner can identify a target as a threat (i.e., not a friendly vehicle), then it can be engaged with the missile. The gunner will need range information to adjust flight and keep track of flight time and to determine if the target is within maximum range of the missile. The laser rangefinder (LRF) is the primary means of determining range, followed by manual estimation with the reticle. The LRF is an eyesafe laser and operates at 1.54-μm wavelength.

The gunner will need to keep the target in the FLIR's field of view to let the guidance logic track the missile flight to target. At sufficient range, the target can use obscurants in an attempt to break lock, by degrading the image presented to the gunner, for enough time to render flight commands to the missile useless. This may be a matter of seconds, and depends upon range to target, type of obscurant used, effects on presented scene, and prevailing conditions (terrain, meteorology). The cloud can degrade the guidance loop as well. Missile flight can take it into or through obscurant clouds. If the cloud is thick enough, it can reduce the beacon emissions below detection thresholds for the tracker.

4. Obscurant Effects

The discussion of OD conditions involves generic values that can be applied to a number of different advanced systems. If specific values for IBAS, Bradley A3, or the missile are available, they should be used instead of these conditions. These conditions are used to illustrate the logic involved in the methodology. OD represents a measure of how much obscurant material is present along a given line of sight (LOS), for a given time. This will vary for an LOS, depending upon weather conditions, wind, and natural cloud variations. OD (optical thickness) is defined as

$$OD = \alpha * CL, \tag{1}$$

2

where α is the extinction coefficient, m^2/g, and CL is the concentration-pathlength integral, g/m^2. This relates to transmission via Beers' Law:

$$\tau = \exp(-\alpha CL) = \exp(-OD). \tag{2}$$

For many advanced weapon systems (included operator-guided), an upper value (VH) for OD was recommended, where system degradation may occur [1]. At levels beyond this value very sensitive (or very expensive), hardware may be needed for operation. A lower value (VL) of OD may also be set; below this value, most systems should operate with no effect from obscurants. For an improved FLIR, operating range and OD values should be defined in the system requirement or specification.

LRF performance depends on the receiver sensitivity, reported in decibels (db). One OD equals about 8.6 dB for two-way transmission through the cloud (4.3 dB for one-way transmission). The laser performance threshold can, therefore, be converted to an equivalent OD or transmission level. Conversely, a performance threshold (in OD) can be related to the sensitivity of the received signal in dB. Upper and lower values of OD, for laser operation, can be derived or measured, similar to that used for a FLIR.

The laser (1.54 μm) shows a spectral mismatch with the FLIR (operates at 8–12 μm); for example, Table 1 shows comparisons of extinction coefficients for some common obscurants, in several bands [2]. The characteristics are also included in combined obscuration model or battlefield-induced contaminants (COMBIC), for obscurant modeling [3]. The mismatch, caused by the difference in extinction coefficients, could mean that the laser may be unable to get the range to target, if the environment contains phosphorous smoke, fog oil, or diesel-generated smoke (VEESS). The three materials have little effect in the far infrared (IR) (unless present in high OD levels), but have significant effects on the visual and near IR. It's possible, under certain conditions, to be able to see a target with the FLIR but be unable to obtain an exact range with a LRF.

Table 1. Comparison of Mass Extinction Coefficients

Obscurant Material	Wavelength Band (μm)			
	Visual 0.4–0.7	Near IR 0.7–1.2	Near IR Laser 1.06	Far IR 8–12
Phosphorous	4.08	1.77	1.37	0.29
Fog Oil	6.85	4.59	3.48	0.02
Diesel Oil (VEESS)	6.85	4.59	3.50	0.02

All three materials discussed in Table 1 are "white" (reflective/scattering) obscurants. The LRF may report a false range, if cloud elements are in the propagation path. The cloud may also scatter the laser pulse to the point where two-way attenuation drops the signal below the receiver's threshold of detection. The target return might be rejected, in favor of a larger pulse from the cloud, unless last-pulse logic is used to find the attenuated return from the target.

Information on the guidance link can be obtained from the sight or missile specification, and from the missile beacon specification. Ratio of energy (power) can be converted to a decibel relationship and, thus, to an equivalent OD. The receiver (tracker unit) may be unable to receive enough energy, above a certain OD, to be able to recognize this as energy from the missile beacon. In this case, a missile guidance link would break and the missile could be lost. This effect may be small at short range but could be significant at extended ranges.

5. Trinary Logic

Some suggestions for "trinary logic," on target engagement and missile hit, are also supplied. These steps are the rough design for an engagement algorithm. They reflect the steps involved for engagement and guidance, where obscurants can affect the fire-control solution or guidance

to the target. These steps can make the modeling and analysis process easier by applying obscurant effects where they have impact on the system.

5.1 Elements to Hit a Target, and Obscurant Effects to Consider.

- Identify the target: obscuration to deceive/distort, lose contrast.

- Get range to target: obscurants degrade laser return, induce false target.

- Launch missile.

- Guide missile to target,

    - obscure or distort target aspect (operator scene), and

    - degrade guidance link from missile (beacon).

- Hit target.

5.2 Logic Steps for Engagement and Ph Determination.

- Get engagement range from scenario and FMs for system.

- Set a critical range (short range) inside which the gunner will displace and evade; the threat is too close.

- While target is beyond critical range do.

    - If a gunner CANNOT identify, then done (fail to engage).

5

- Else, if a gunner CANNOT range to target, then use manual range estimate (reticle) (degrades ballistic solution).

- Else, if the range to target is NOT similar to known terrain features at range, then use manual estimate (degrades ballistic solution).

- Else, accept laser range to target.

- Launch/fire missile.

• While missile flight increment is less than range to target, do the following.

- If a gunner CANNOT keep target in field of view, then missile lost.

- Else, do the following.

  • If obscurant level is NOT above complete defeat threshold, then missile lost (guidance link defeat).

  • Else, if obscurant level is NOT below effect threshold, then missile unaffected by obscurant.

  • Else, degrade missile tracking ability by linear function of transmission level (crude, but it can be fitted to other curves or known data if available).

    - If random draw is less than tracking ability, then missile lost.

      · Else, adjust missile position by random value due to effects on beacon/receiver link.

- Increment missile flight segment toward target (velocity vector, time, and beacon shift).

- Done with flight.

- Obtain hit point by examining missile position and attitude, as adjusted by cloud effects on tracker.

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